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A Methodology for the Analysis of Conventional and Nuclear Prompt Global Strike Alternatives

OPERATIONS RESEARCH CENTER OF EXCELLENCE
TECHNICAL REPORT DSE-TR-0909
DTIC #: ADA500533

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Deputy Director, Operations Research Center of Excellence

Approved by

Colonel Timothy E. Trainor, Ph.D.
Professor and Head, Department of Systems Engineering

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Abstract

The Quadrennial Defense Review in 2006 made several decisions which affect US Strategic Command's (USSTRATCOM) mission areas, specifically in the area of conventional prompt global strike (CPGS) capability. There is a need for analysis of issues associated with USSTRATCOM lines of operation in the areas of Strategic Deterrence/Nuclear Operations. Global Strike with respect to the conventional strike capability is explored to include prompt global strike as a follow-on to the joint force enabler to respond to various threats.

The Systems Decision Process (SDP) is applied to analyze CPGS alternatives based on a value focused thinking methodology in order to develop a strategy for meeting the challenges of today and to help prioritize the implementation of this strategy.

About the Author

Lieutenant Colonel (LTC) Suzanne DeLong graduated from the United States Military Academy in 1990 and was commissioned a Second Lieutenant, serving as an Air Defense Artillery Officer and commanded at the Platoon and Battery level in the HAWK and PATRIOT Weapon Systems. Military assignments include Germany; Ft. Bliss, Texas; Ft. Hood, Texas; Saudi Arabia; United States Military Academy, and Fort Monroe, Virginia. Having completed her advanced civil schooling at the University of Virginia, LTC DeLong is currently serving as an Operations Researcher\Systems Analyst and an Assistant Professor in the Department of Systems Engineering at the United States Military Academy (USMA) and is the Deputy Director for the Operations Research Center (ORCEN).

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Chapter 1: Introduction

The 2006 Quadrennial Defense Review (QDR) resulted in the following four decisions. The first decision is to develop a new land-based, penetrating long-range strike capability to be fielded by 2018 while modernizing the current bomber force. Second, within two years, deploy an initial capability to deliver precision-guided conventional warheads using long-range Trident Submarine Launched Ballistic Missiles (SLBM). Third, designate the Defense Threat Reduction Agency (DTRA) as the primary Combat Support Agency for U.S. Strategic Command (USSTRATCOM) in its role as lead Combatant Commander for integrating and synchronizing combating weapons of mass destruction (WMD) efforts. Fourth, improve and expand U.S. forces' capabilities to locate, track and tag shipments of WMD, missiles and related materials, including the transportation means used to move such items.

In response to these decisions, several studies have been prepared by various agencies in order to establish the way ahead to meet the expectations of the decisions presented. Several issues have been cited by Congress in response to these studies. First, with respect to an initial capability to deliver precision-guided conventional warheads using long-range Trident SLBM's, Congress has identified "nuclear ambiguity" and a high risk of a mistaken nuclear first strike. Second, Congress has cited availability and reliability of intelligence assets as an issue with respect to the enabling capabilities for conventional prompt global strike (CPGS) employment. Third, the absence of transparency and accountability with regard to the decision making process of when to employ CPGS. Fourth, the international legal implications with regards to notification before and during CPGS employment are of concern.

USSTRATCOM, in preparation for QDR 2009, commissioned this study to analyze the CPGS problem in support of a way ahead in future force development with respect to strategic

deterrence. A literature review was conducted in order to fully understand the problem at hand and to be able to understand the implications of the 2006 QDR decisions. The Systems Decision Process (SDP) is applied to the problem with a value focused thinking methodology. This encompassed defining the problem through stakeholder analysis, functional decomposition and value modeling which resulted in a revised problem statement and value hierarchy. Alternatives were generated and then scored as a result of the value modeling in order to gain insight into the value each alternative holds with respect to the stakeholder ideals. As a result of this research, a strategy and prioritization for CPGS and nuclear prompt global strike (NPGS) systems is suggested for meeting future challenges.

1.1 Project Overview

A literature review consisting of papers, studies, master theses and journal articles are summarized in Chapter 2. Chapter 3 discusses the Systems Decision Process (SDP) which is the methodology being applied to this problem. Chapter 4 details the problem definition phase of the SDP and its application to the problem and results in the functional hierarchy, value model and revised problem statement. Chapter 5 defines the alternatives as a result of alternative generation. Chapter 6 discusses the decision making process through scoring the candidate alternatives. Multi-objective decision analysis is applied across the feasible alternatives and results in total value scores for each alternative. Chapter 7 addresses the assessment of the threat and introduces a decision tree tool in which to assess the threat. Chapter 8 applies the methodology and presents results for the nuclear prompt global strike problem (NPGS). Chapter 9 provides the summary and conclusions given this analysis and Chapter 10 suggests future work for analysis in this area.

1.2 Constraints, Limitations and Assumptions

Constraints, limitations and assumptions bearing on the problem are addressed as a result of the literature review and stakeholder analyses which are discussed in chapters 2 and 4 respectively. USSTRATCOM conducted a conference with the PGS key players which also helped to shape the constraints, limitations and assumptions.

The following four constraints were identified through the literature review. The total time from deployment to engagement is 60 minutes or less, the probability of launching on schedule must be 95% or greater, system reliability must be 98% or greater and the systems availability should be 90% or greater.

There are three limitations that were identified for this study. In keeping this study unclassified, only unclassified data is used. The tools and methodology are easily adapted for a classified study by substituting the raw data with classified data. It was determined that while rare, there are certain extreme weather conditions that may limit the use of particular systems. Lastly, there are limitations on the system response times. These limitations are as follows: Tactical Ballistic Missiles (TBMs) take 2-4 hours to deploy, set up, and launch, Air Expeditionary Forces (AEF's) distant air strikes from the United States need massive logistic support and in-theater escorts, and there are too few Carrier Battle Groups (CBG's) to cover all threat spots and they are limited to strikes of only a few hundred miles from the carrier.

There are two assumptions. We will assume that given a threat and its location, the systems are set up and at full alert status 24 hours per day and 7 days a week within range of that threat. It is also assumed that with the expiration of the Strategic Arms Reduction Treaty (START) in December 2009, the alternatives considered here will still be within compliance of

all treaties, codes or pacts developed in the future. Table 1 below summarizes the constraints, limitations and assumptions:

Table 1. Constraints, Limitations and Assumptions

Constraints	Limitations	Assumptions
Total Time $\leq$ 60 min	Data (unclassified)	Systems are set up and at full alert status 24/7
P(Launch on schedule) $\geq$ 0.95	Systems limited by weather conditions	All alternatives considered are within compliance of future treaties, codes or pacts
Reliability $\geq$ 98%	System response times	
Availability $\geq$ 90%		

Chapter 2: Literature Review

This literature review consists of papers from the Air Force and Navy perspectives as well as from independent sources as cited. A summary of each of the sources is provided below.

2.1 Air Force Perspective

The Air Force "Prompt Global Strike (PGS) Analysis of Alternatives (AoA) Study Plan", dated 28 October 2005, discusses the methodology that should be applied when analyzing the PGS problem but is not an analysis of alternatives. This report will result in an analysis of alternatives based on a value focused thinking methodology as described in Chapter 4 and in Parnell, Driscoll and Henderson, 2008.

A study by Bille and Lorentz addresses "Requirements for a Conventional Prompt Global Strike Capability" and was presented at the National Defense Industrial Association (NDIA) Missile and Rockets Symposium and Exhibition in May 2001. This study emphasizes the need for PGS and suggests the following PGS system options: Hypersonic Cruise Vehicle, Inter-

continental Ballistic Missile (ICBM) or SLBM, Air Launched Missile, Space operations vehicle or a space based launch platform.

A dissertation by MAJ Timothy Jorris, titled “Common Aero Vehicle Autonomous Reentry Trajectory Optimization Satisfying Waypoint and No-Fly Zone Constraints”, was completed at the Air Force Institute of Technology (AFIT) in September 2007. This dissertation explores the Force Application Launch from the Continental United States (FALCON) program, and the National Aeronautics and Space Administration (NASA) Next Generation Launch Technology (NGLT) Program and addresses the Common Aero Vehicle (CAV) alternative.

A briefing from COL Rick Patenaude in August 2005 provides a “PGS Update” to include alternatives and addresses the nuclear ambiguity problem.

2.2 Navy Perspective

In 2008, the Naval Studies Board (NSB) published “U.S. Conventional Prompt Global Strike: Issues for 2008 and Beyond”. This study analyzes the need for CPGS; CPGS System alternatives and their implications for stability, doctrine, decision making and operation; what ambiguities and arms control issues arise from these systems and how they can be mitigated; and the research, development, testing and evaluation of the Conventional Trident Modification (CTM) Program.

2.3 Independent Sources

The QDR Report, dated February 6, 2006, summarizes the findings of the QDR in its effort to “reorient the Department’s capabilities and forces to be more agile in this time of war and implementing enterprise-wide changes to ensure that organizational structures processes and procedures effectively support its strategic direction”. This report gives specific guidance and decisions with respect to “tailored deterrence” and the “new triad”. Progress with respect to this

field includes the retirement of the Peacekeeper ICBM, the decommissioning of four ballistic missile submarines (BMS) from strategic nuclear service and hundreds of warheads removed from the Minuteman III ICBM's.

"Conventional Prompt Global Strike: Valuable Military Operation or Threat to Global Stability" by Todd C. Shull (2005), "examines the potential destabilizing implications of CPGS capabilities that operate from or through space".

"Conventional Warheads for Long-Range Ballistic Missiles: Background and Issues for Congress" by Amy Woolf (2008), summarizes the current alternatives and associated issues and advocates long-range ballistic missiles because of their advantage over sea-based systems especially if Naval forces are not in vicinity of the conflict area.

"An examination of the Pentagon's Prompt Global Strike Program: Rationale, Implementation, and Risks" by Vince Manzo (2008), summarizes the issues to date with the implementation of PGS programs.

"Global Strike: A Chronology of the Pentagon's New Offensive Strike Plan" by Hans M. Kristensen (2006), discusses the plan to implement the conversion of the Trident into a conventional missile by November 2010. The literature reveals that congress has not approved the funding for this alternative to date.

Grossman (2008) reports in Government Executive.Com the Magazine on August 15, 2008 that an independent panel advised the Navy to convert the Trident missile to a conventional weapon. This alternative has brought concern with congress with regards to the nuclear ambiguity issues.

The report of the Defense Science Board (DSB) Task Force on Future Strategic Strike Forces, February 2004, looked 30 years into the future in order to give the "President an

integrated, flexible and highly reliable set of strike options with today's tactical-level flexibility but on a global scale". Recommendations are made in the area of command and control; intelligence, surveillance and reconnaissance and battle damage assessment (BDA); delivery systems; and payloads. With respect to delivery systems the report recommends converting Peacekeeper ICBMs to conventional weapon systems and the development of a Navy intermediate-range ballistic missile.

"Technological Implications of the 2006 QDR", by Robert Martinage, is a briefing that identifies CPGS alternatives and challenges; identifies the QDR's four priorities and the technological challenges with each one.

2.4 Treaties, Codes and Pacts

This paragraph highlights some of the key legal implications as they pertain to CPGS. One of the key documents, the START expires on December 5, 2009, and places ceilings on US and Russian deployments of nuclear warheads and strategic delivery vehicles (ICBMs, SLBMs and heavy bombers) (Boese, 2005). The Obama administration is currently conducting the nuclear posture review and has promised that a new treaty will be in effect before the end of 2009.

A Launch Notification Agreement is an agreement between the US and Russia on notifications of launches of intercontinental ballistic missiles and submarine-launched ballistic missiles (SLBMs). (Shull, 2005)

The Strategic Offensive Reductions Treaty (SORT) expires at the end of 2012 and limits only warheads. (Boese, 2005)

The 2002 Hague Code of Conduct (HCC) Against Ballistic Missile Proliferation calls for greater restraint in developing, testing, using, and spreading ballistic missiles. (Davis and Dodd, 2006)

The "Missile Technology Control Regime (MTCR) is a voluntary co-operative undertaking between states to limit the proliferation of nuclear, and (since January 1993) chemical and biological-capable missiles with a range of over 300 km. There are several major weaknesses in the MTCR. First, it is not a treaty and is not legally binding. Second, not all the suppliers of missile components and technology are in the regime (e.g. China, North Korea, Iran, India and Pakistan are suppliers who operate outside of the MTCR, although China has pledged to work within MTCR guidelines). Third, the regime contains no provisions for reducing existing missile stockpiles, and fourth, it denies dual-use technology to developing countries for peaceful purposes." (Davis, et al., 2006)

Another consideration is the Liability Convention of 1972 which was a convention on international liability for damage caused by space objects and the Multilateral Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (Outer Space Treaty).(Shull, 2005)

2.5 Issues

Some issues have been raised with regards to CPGS that have prevented congress from funding CPGS projects. The National Academy of Sciences (NAS) Committee on CPGS Capability argued that virtually any long-range weapon built for the mission might introduce some risk of the nuclear "ambiguity" that Congress seeks to avoid.(Grossman, 2008) This could inadvertently cause a high risk of a mistaken nuclear first-strike.

"International legal implications\complications with regards to territorial sovereignty, international and sovereign airspace may undermine the HCC Against Ballistic Missile Proliferation thereby possibly introducing a new arms race in ballistic missiles and countermeasures as other countries seek to match the US system and/or seek to protect their sovereignty by building weapon systems to counter US capabilities. It seems likely, for example, that other nuclear powers, such as China and Russia, would embark on similar SLBM and ICBM conversion projects. This could in turn ratchet up the potential for major armed conflict in areas, such as the Taiwan Straits, where tensions already run high." (Shull, 2005)

The cost to US taxpayers is an issue. The question has been raised on whether a CPGS project is morally or ethically justifiable or indeed a wise investment of US taxpayers' money. The costs are estimated at $500 million. "While CPGS may provide a limited deterrence against threats posed by state actors, it offers little viable defense against 'asymmetric' threats posed by non-state actors where there is no, or an unproven, 'return address'. Some of the most devastating attacks against the United States, such as the Oklahoma City bombing and the attacks of 9/11, have occurred on home soil. Conventionally armed ICBMs would do nothing to deter similar attacks in the future and it is unlikely that they could realistically shape a military response to future attacks perpetrated in the same vein". (Grossman, 2008)

Additionally, the British American Security Information Council (BASIC) recommended that Congress eliminate the $127 million earmarked in the Fiscal Year 2007 budget to modify 24 of the US Navy's Trident II D-5 SLBMs to conventional warheads; and NATO Member States and other US allies helped Congress to eliminate this proposal by voicing opposition to it, both in public as well as in private conversations with US officials. This international opposition obviously must be considered. (Davis et al., 2006)

2.6 Summary

Senior civilian and military leaders identified four priorities as the focus of the 2006 QDR. Defeating terrorist networks, defending the homeland in depth, shaping the choices of countries at strategic crossroads and preventing hostile states and non-state actors from acquiring or using WMD. The QDR four key tasks were to determine the major challenges that the United States may have to confront over the next 20 years, to present a strategy for meeting these challenges, to assess whether the force structure and defense program proposed by the Defense Department are consistent with the diagnosis of the threats and the strategy proposed for addressing them and to estimate the level of resources necessary to implement this strategy. (QDR Report, 2006)

Finally, four QDR decisions were spelled out. To develop a new land-based, penetrating long-range strike capability to be fielded by 2018 while modernizing the current bomber force; within two years, deploy an initial capability to deliver precision-guided conventional warheads using long-range Trident Submarine- Launched Ballistic Missiles; to designate the Defense Threat Reduction Agency as the primary Combat Support Agency for USSTRATCOM in its role as lead Combatant Commander for integrating and synchronizing combating WMD efforts and to improve and expand U.S. forces' capabilities to locate, track and tag shipments of WMD, missiles and related materials, including the transportation means used to move such items. (QDR Report, 2006)

This literature review highlighted several challenges. First, striking targets over intercontinental distances rapidly and without warning, missile launch responsiveness, time of flight of the missile, compensating for target location error (mobile target problem), and defeating hardened and deeply buried targets. Some initial ideas on potential technology areas

include conventionally armed SLBMs; a short-term solution of converted D-5s with GPS-assisted INS and maneuvering RVs; a long-term solution of lower cost system exploiting advances in miniaturization and high-energy density propellants; reusable space launch vehicles (SLVs) and common aero vehicles (CAVs); hypersonic cruise vehicles (space planes); and advanced propulsion and materials.

With the 2006 QDR priorities, key tasks and decisions as well as the issues with each of these items in mind, this paper will present a strategy for meeting the CPGS challenges and prioritization for implementing the strategy.

Chapter 3: Systems Decision Process

3.1 Overview

The Systems Decision Process (SDP) is a methodical process in which to analyze and solve problems. Figure 1 below depicts the SDP which is the process that is taught to cadets in the Department of Systems Engineering at West Point. See Parnell, et al. (2008) for a thorough description of this process and its implementation.

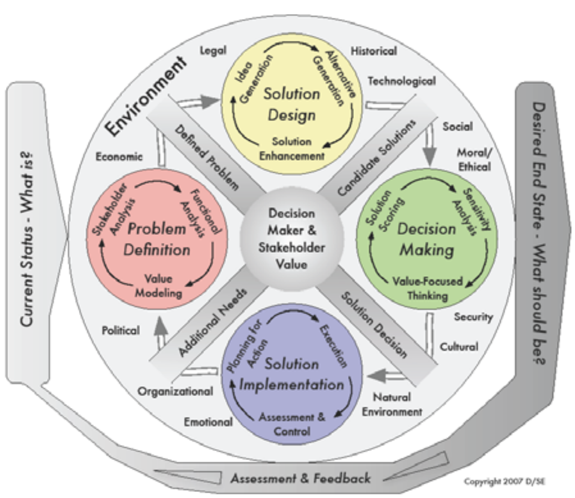

Figure 1. Systems Decision Process

First we define the system and the associated system boundaries. Figure 2 below from Parnell, et al. (2008) depicts the structural organization of a system with boundaries. We are concerned with CPGS Systems and must establish the boundaries around which we will scope the problem. Our system consists of the processes and components that enable and execute a global strike mission. The system is discussed in greater detail in the next section addressing functional analysis. The inputs to this system are our intelligence estimates and information about the threats. The outputs from this system are the reports of our system status and the outcome of the threat status as a result of employing the system.

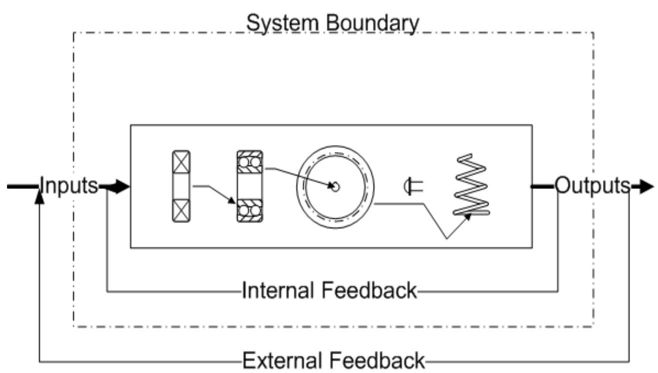

Figure 2. Structural organization of a system with boundaries

In further defining the problem we must conduct a stakeholder analysis in order to determine the people and organizations that have a "stake" in the decision process and help us to define the problem with respect to their needs, wants and desires as they pertain to the problem. Stakeholders help us define the functions, objectives and value measures which make up the value hierarchy which is discussed in greater detail later. The stakeholder analysis allows us to also consider other issues such as political, economic, social, ethical and technological aspects that may also impact the system. (Parnell, et al., 2008) Some techniques to conducting the

stakeholder analysis in order to gather this information are conducting interviews, developing focus groups, conducting surveys and brainstorming sessions and conducting research. Parnell, et al., describes each of these activities in great detail.

The value hierarchy depicts the functions, their objectives and the value measures used to measure the obtainment of the objectives. Figure 3 below is a schematic of the value hierarchy.

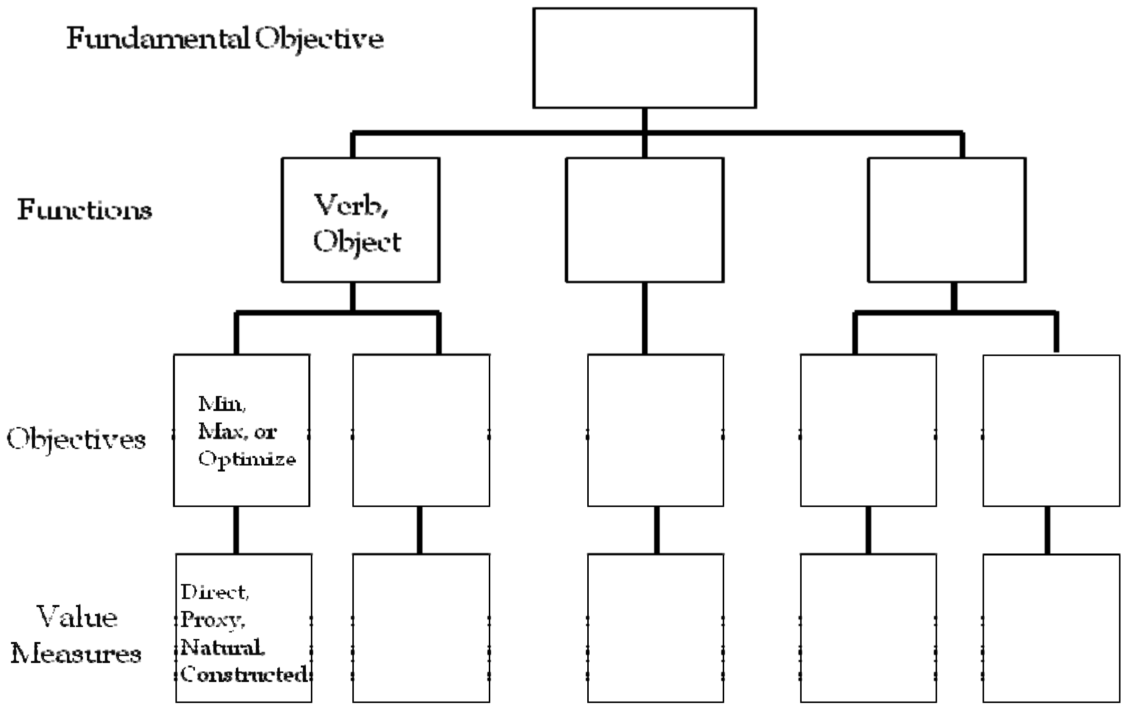

Figure 3. Value Hierarchy

The functions, objectives and value measures make up what is called the value hierarchy. Value curves are developed by the analyst in conjunction with the client to reflect the client's preferences in terms of their organizational values for each of the functions and objectives. These value curves help us in the process of scoring the alternatives developed during the next phase of the SDP. See Parnell, et al. (2008) for the detailed process of developing and utilizing value curves.

Chapter 4: Problem Definition

The first step in applying the SDP is the problem definition phase. This phase consists of stakeholder analysis, functional analysis and value modeling. This chapter will address each of these steps in this phase as applied to this problem.

4.1 Stakeholder Analysis

As USSTRATCOM, J811 prepared for the 2009 QDR, they sought outside assistance with analysis of issues associated with the USSTRATCOM mission area of Strategic Deterrence/Nuclear Operations. In further refining this initial problem statement, the stakeholders were identified and analyses of the stakeholders' needs that pertain to this problem were researched as interview with other organizations were not permitted by the client. It would have been beneficial to have Joint Functional Component Command for Global Strike and Integration (JFCC-GSI) input to this process.

The stakeholders are classified as the client, the customer, the users and any others that may hold a "stake" in this problem. Our client and customer is STRATCOM J811. The users of this system consist of STRATCOM JFCC GSI. Agencies concerned with this system include the Department of Defense (DoD) (Joint, Army, Navy, and Air Force), Congress, National Command Authorities (NCA), the Intelligence Community, the President of the United States, and our North Atlantic Treaty Organization (NATO) Allies.

Much of the information obtained through the literature review forms the basis for the stakeholder analysis and therefore spans multiple perspectives in order to capture the values of organizations such as those identified above in the classification of the stakeholders.

4.2 Functional Analysis

The functional analysis captures the systems functions and sub-functions (and further sub-functions down to the required level) and associated issues\concerns. An exhaustive list of the functions is identified within the constraints of the system boundary identified previously. We begin our analysis with the USSTRATCOM mission and functions in order to frame the problem within the context of the organization. Figure 4 details the functional decomposition of USSTRATCOM.

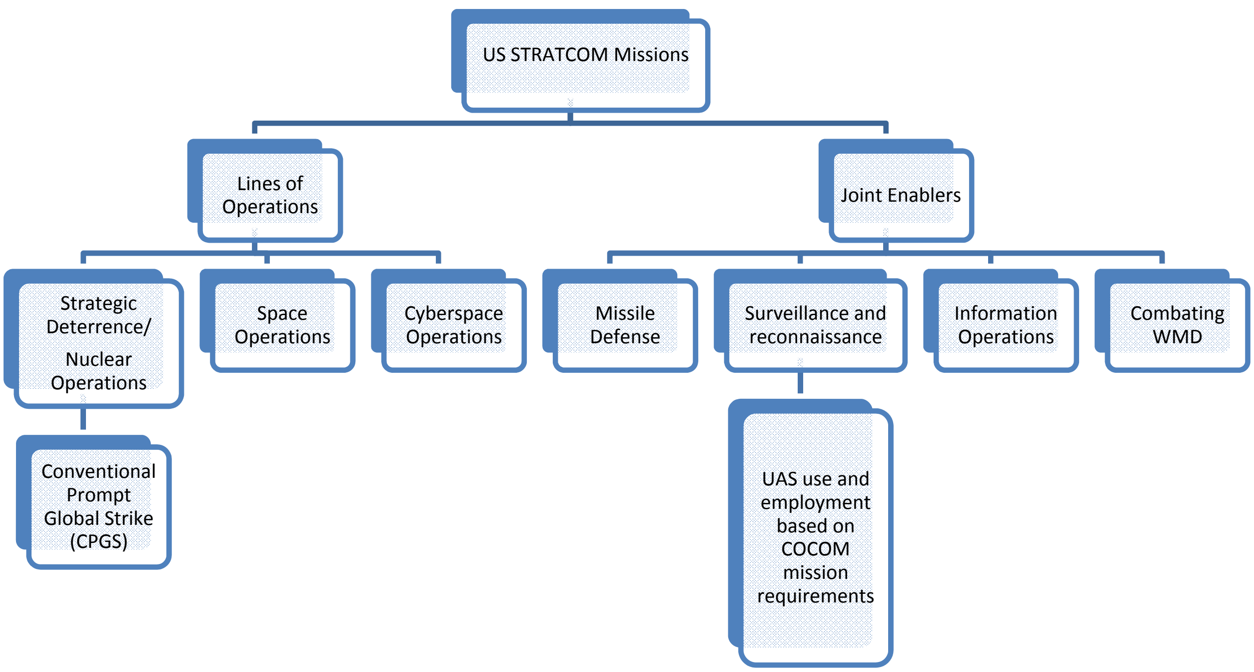

Figure 4. USSTRATCOM Functional Decomposition

The mission area of strategic deterrence\nuclear operations contains the CPGS function.

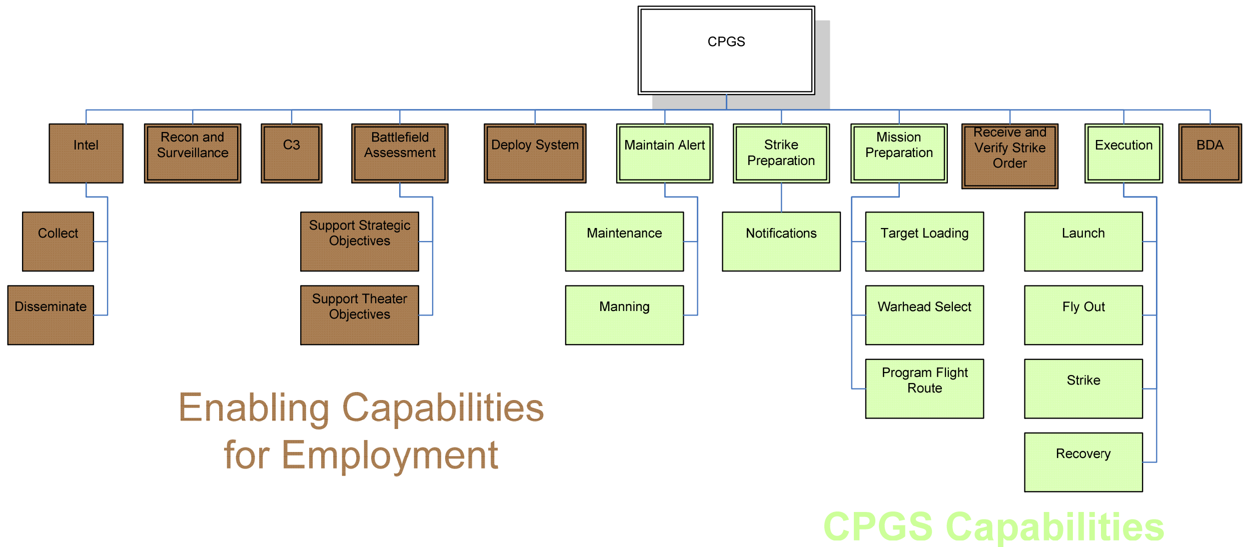

Figure 5 below is the functional decomposition of CPGS. These functions have been identified as enabling capabilities, shown in brown, versus CPGS capabilities, shown in green. It was recognized that in evaluating alternatives, the enabling capabilities do not differ given the different alternatives. For instance, the process of collection and dissemination of intelligence is the same for each alternative and therefore will contribute equally to each alternatives score. Therefore these functions will not be included in the value hierarchy but should be considered as the functions that help to enable CPGS. Without these functions, CPGS will not be possible.

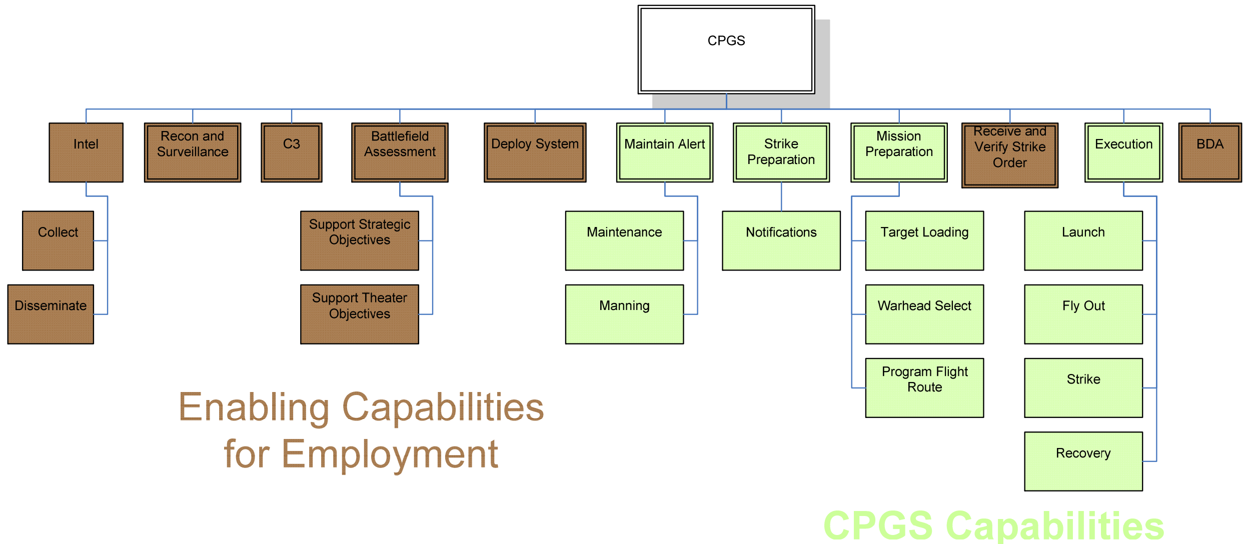

Figure 5. CPGS Functional Decomposition

The literature review reveals the following functional issues. The availability of the enabling capabilities for CPGS employment especially the intelligence functions, the absence of transparency and accountability, the high risk of mistaken nuclear first strike, international legal implications, potentially a new arms race in ballistic missiles, launch responsiveness, time of flight to engage the target, target location error (mobile target), defeating hardened and deeply buried targets and cost. (Manzo, 2008)

4.3 Systems Concepts

The Air Force PGS AoA plan (2005) identified and defined some system concepts that are helpful in the development of new systems or conversions. Table 2 below summarizes these system concepts.

Table 2. PGS System Concepts

System Concept	Definition
High speed strike system	development/adaptation of a piloted, remotely controlled, or autonomous subsonic/supersonic/hypersonic vehicle (aircraft, sea

	craft, or missile) to deliver precision standoff or direct attack subsonic/supersonic/hypersonic munitions.
Operationally responsive space	expendable and/or reusable launch vehicle that can deliver precision guided munitions.
Military space plane	reusable launch vehicle that could directly deliver precision guided munitions.
Ground or sea-based expendable launch vehicle	an approach that consists of either modification of current space launch vehicles, conversion of deactivated intercontinental ballistic missiles or sea-launched ballistic missiles, or building a new launch vehicle to deliver weapon payloads; such as small launch vehicle or submarine launched intermediate range ballistic missiles. The advanced reentry vehicle/body such as a common aero vehicle could be developed to accompany these missile systems.
Air-launched global strike system	an aircraft that air-launches Pegasus-like space launch vehicles configured with weapons and/or an aircraft delivering supersonic or hypersonic long-range cruise missiles.

4.4 Strategic Strike Targets

In analyzing the CPGS problem the target sets are identified in order to fully analyze the alternatives and their capabilities. The targets for strategic strike are the objects of greatest value to an adversary and include the following target sets as identified by the DSB in February, 2004: weapons of mass destruction (deployed forces, storage and production facilities); leadership (command bunkers, residences, political control assets, economic assets); other military assets (command, control, and communications (C3); intelligence, surveillance, and reconnaissance (ISR); air and naval bases; other military infrastructure; special targets (hard and deeply buried targets (HDBT), fleeting targets, agent defeat); and specific assets or functions known to be of significant value to the leadership. It is important that the CPGS systems be able to defeat these target sets.

4.5 Value Modeling

Value modeling focused on the functions that varied across alternatives. All of the enabling capabilities were excluded from the value modeling as these functions are considered to

have the same value regardless of the alternative. Table 3 below shows the CPGS value hierarchy which is comprised of the functions, sub-functions and a sub-sub-function with their objectives and value measures. The value hierarchy is a very important tool as it lays out the criteria on which to judge the alternatives. This tool must have stakeholder buy in. The stakeholder with the assistance of the analyst will also weight the value measures which will be extremely important as this will directly affect the alternative scoring discussed next in Chapter 5.

Table 3. CPGS Value Hierarchy

5.0 Deploy System		6.0 Maintain Alert		7.0 Strike Preparation	8.0 Mission Preparation				10.0 Execution				
Send System to Theater	Set Up System	System Maintenance	System Manning	Pre-launch system prep	Target Loading	Warhead Select (munitions payload capacity)		Program Flight Route	Launch	Fly Out	Strike		Recovery
									All-weather launch				
Minimize Time	Minimize Time	Minimize Maintenance Overhead	Minimize Manning Overhead	Minimize Preparation Time	Minimize Target Loading Time	Maximize Appropriate Warhead Selection	Minimize Threat of Nuclear Launch	Minimize Time to Program Flight Route	Maximize Launch Responsiveness	Minimize Time to Target	Minimize Target Location Error	Maximize Target Destruction	Minimize Recovery Effort
Time to Arrive in Theater (Hrs)	Time to System Ready (Hrs)	Time (hrs) and reliability To Maintain	Time to train (hrs) (training needed to maintain proficiency)	Time to Prepare (min) given intel report	Time to Load (min)	Damage Radius (m)	Prob of Interpreting as a Nuclear Launch	Time to Program (min)	Launch Responsiveness (hrs)	Range (nmi)\Time to Target (min)	CEP (nm)	SSKP	Time to Recover (min)

It is important to address the question of what is the impact of the current processes on operational capabilities with respect to conventional strike capability. Manzo (2008) states that "The Prompt Global Strike (PGS) program aims to enable the United States to plan and deliver military strikes anywhere on the globe in less than one hour. The rationale for the PGS mission is that new capabilities are required to effectively respond to new threats." The issues addressed with the 2006 QDR as well as information from the Air Force, Navy and independent perspectives are important in developing the revised problem statement.

In consideration of the information learned as a result of this research, the literature review, stakeholder and functional analysis, value hierarchy development and feedback from STRATCOM J811, a revised problem statement is written to fully capture the scope of this problem and the system boundaries. The revised problem statement is as follows: the DoD needs to develop CPGS capabilities and the enabling capabilities in order to allow the global war-fighters in space to hold the adversary at risk through strategic deterrence NLT 2018.

Chapter 5: Alternative Analysis

5.1 Generating Alternatives

Brainstorming and brain writing are two primary methods of generating alternatives. The literature review also yielded significant information about potential alternatives. This section will summarize all potential alternatives for CPGS while looking at land, air, sea and space based alternatives.

Existing systems consist of "tactical aircraft, cruise missiles, other armed unmanned aerial vehicles and heavy bombers. (Naval Studies Board, 2008) Current air based system alternatives include the B1B, B-2A and the B52H. Current sea based alternatives include ship launched Tomahawk Land Attack Missile (T-LAM) and ballistic missile submarine (BMS). A current space based alternative does not exist to date.

The primary alternatives considered for conversions of their current nuclear systems to conventional systems include the land based Minuteman (MM) III and Peacekeeper (PK) Intercontinental Ballistic Missiles (ICBMs) and the sea based submarine launched conventional TRIDENT modification (CTM).

New developments include the land based common aero vehicle (CAV), other reentry vehicles and the conventional strike missile (CSM) Boost Glide Missile; the sea based

conventional TRIDENT modification 2 (CTM-2) and the hypersonic cruise missile (CM), and the submarine launched global strike missile (GSM); and a notional space based alternative. Table 4 below summarizes these alternatives.

Table 4. CPGS Alternatives

	Current	**Conversions**	**New Developments**
Land		Minuteman III	CAV
		Peacekeeper	Other reentry vehicles
			CSM boost glide missile
Air	B1B		
	B-2A		
	B52H		
Sea	T-LAM	CTM	CTM-2
	BMS		Hypersonic CM
			GSM
Space			Notional

5.2 Feasibility Screening

A set of screening criteria is determined through the stakeholder analysis and takes into consideration the constraints, limitations and assumptions on the problem. Applying these to the alternatives narrows down the alternatives so that we focus on only feasible alternatives. This may also lead us to realize that we may need to relax the constraints as they may result in no feasible alternatives to consider. The criteria for feasibility screening are further defined here. The response time of less than or equal to an hour is from the time CPGS is needed to the time the target is intercepted. An all weather capability requires that the system be fully capable of executing the mission regardless of the weather conditions. The 2006 QDR has indicated that the CPGS capabilities should be available NLT 2012 and must abide by the current laws, treaties

and pacts. In keeping with the STRATCOM mission, the CPGS capability should be a strategic deterrent to the threat.

Given these initial screening criteria, six alternatives are eliminated from consideration as they will not have an initial operating capability by 2012 and in addition, the space based notional alternative does not comply with the Liability Convention or the Outer Space Treaty. The alternatives and their availability dates are as follows: other reentry vehicles in 2020; CSM Boost Glide Missile in 2017, CTM-2 in 2013, Hypersonic Cruise Missile in 2025, the GSM in 2015 and the space based notional alternative in the distant future. If we relax the constraint for availability to the year 2018 as written in the revised problem statement, other reentry vehicles, Hypersonic Cruise Missile, and the space based notional alternative are the infeasible alternatives. The alternatives must score a go for each of the screening criteria in order to be assessed as an overall “Go” to be further considered. The alternatives that will go forward for consideration therefore are the land based alternatives of the Minuteman III, the Peacekeeper missile, the CAV and the CSM Boost glide and. The air based alternatives are the B1B, the B-2A and the B52H. The sea based alternatives are the Tomahawk LAM, BMS and the CTM and CTM-2. These alternatives are further evaluated as the SDP continues with the next step of modeling the alternatives.

Table 5 below shows the results of the feasibility screening after applying the constraints, limitations and assumptions.

Table 5. Feasibility Screening

Criteria/ Alternatives	Response Time ≤ 1 Hour	All Weather Capable	Available by 2018	Legal, Treaty Pacts Compliance	Strategic Deterrent	Overall Assessment

Land	MM III	Go	Go	Go	Go	Go	Go
	PK	Go	Go	Go	Go	Go	Go
	CAV	Go	Go	Go	Go	Go	Go
	Other Reentry Vehicles	Go	Go	No Go 2020	Go	Go	Go
	CSM boost glide missile	Go	Go	Go	Go	Go	No Go
Air	B1B	Go	Go	Go	Go	Go	Go
	B-2A	Go	Go	Go	Go	Go	Go
	B52H	Go	Go	Go	Go	Go	Go
Sea	T-LAM	Go	Go	Go	Go	Go	Go
	BMS	Go	Go	Go	Go	Go	Go
	CTM	Go	Go	Go	Go	Go	Go
	CTM-2	Go	Go	Go	Go	Go	Go
	Hypersonic CM	Go	Go	No Go 2025	Go	Go	No Go
	GSM	Go	Go	Go	Go	Go	Go
Space	Notional	Go	Go	No Go	No Go Liability Convention and Outer Space Treaty	Go	No Go

5.3 Modeling Alternatives

Using the value hierarchy introduced in Chapter 4, each alternative is evaluated using the value measures developed. This involves collecting the data for each value measure for each alternative. The data collection process is a result of research and modeling efforts. When the research doesn't yield the information we need we model the alternative. We can model the alternatives through simulation or mathematical modeling in order to collect the data that is needed. This data is accumulated in what is called the raw data matrix. The value measures from the value hierarchy are summarized in Table 6 below. USSTRATCOM has not provided any feedback on these value measures. Ideally, the client provides feedback on these so the final

analysis has buy in and reflects the stakeholders' desires. These value measures will be used in order to demonstrate the rest of the SDP.

Table 6. Value Measures

Value measure	Unit of Measure
5.1 Time to deploy system to theater	Hours
5.2 Time to set up system	Hours
6.1 Maintenance time prior to launch	Hours
6.2 Time to train personnel for system manning	Hours
7.0 Time to prepare for strike	Hours
8.1 Time to load target	Hours
8.2.1 Blast Radius	Miles
8.2.2 Probability of mistaken nuclear strike	Probability
8.3 Time to program launch	Minutes
10.1 Launch responsiveness	Hours
10.2 Time to target	Minutes
10.3.1 Circular Error Probable	Nautical Miles
10.3.2 Single Shot Kill Probability	Probability
10.4 Time to next launch	Minutes

Table 7 shows the raw data matrix for all the feasible alternatives given the above value measures and assumes the worst case scenario for each alternative when given a range of values. The ideal alternative is shown for benchmarking purposes and allows a comparison that reveals what improvements are needed for the alternative to be closer to the ideal alternative.

Table 7. Raw Data Matrix

EM/ Alternatives		5.1	5.2	6.1	6.2	7.0	8.1	8.2.1	8.2.2	8.3	10.1	10.2	10.3.1	10.3.2	10.4
Land	MM III	1	0	1	1	1	0	4	.9	5	1	20	.2	95	20
	PK	1	0	1	1	1	0	4	.9	5	1	20	.2	95	20
	CAV	1	0	1	1	1	0	4	.9	5	1	20	.2	95	20
	CSM BGL	1	0	1	1	1	0	4	.9	5	1	20	.01	95	20
Air	B1B	3	2	5	5	5	1	1	.5	10	2	60	.02	80	10
	B-2A	3	2	5	5	5	1	1	.5	10	2	60	.02	80	10

	B52H	3	2	5	5	5	1	1	.5	10	2	60	.02	80	10
Sea	**T-LAM**	5	2	5	5	5	1	1	.5	10	2	80	.25	60	10
	BMS	5	2	5	5	5	1	1	.5	10	2	80	.25	60	10
	CTM	5	2	5	5	5	1	1	.5	10	2	80	.25	60	10
	CTM-2	5	2	5	5	5	1	1	.5	10	2	80	.25	60	10
	GSM	5	2	5	5	5	1	1	.5	10	2	80	.25	60	10
Ideal		0	0	0	0	0	0	0	0	0	0	0	0	100	0

Not being able to obtain reliable data for each alternative given the value measures, we cannot distinguish between the alternatives in each of the categories for land, air and sea alternatives and therefore our analysis will now focus on the system categories in order to distinguish between the land, air and sea alternatives.

Chapter 6: Decision Making

6.1 Scoring Candidate Solutions

Value functions are developed for each value measure. The raw data is then converted to a value score based on the value functions and summarized in the value matrix. The additive value model is then computed by multiplying the value matrix by the swing weight solution and a total value score is found for each alternative.

6.1.1. Value Functions

Value functions are developed in close coordination with the stakeholder in order to capture the stakeholder's beliefs with respect to the value of the parameters for the value measure. The stakeholder is instrumental in identifying what the shape of the value curves should look like. Figures 6 – 19 depict the value curves for the value measures shown in Table 6. The value is some number between 0 and 10 and is defined by the value curves below.

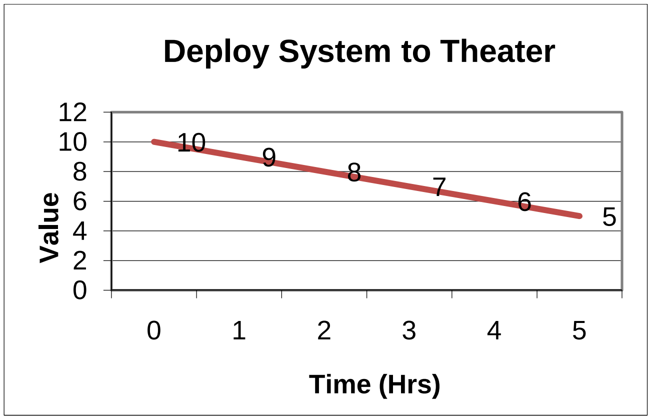

Figure 6. Value Function 5.1

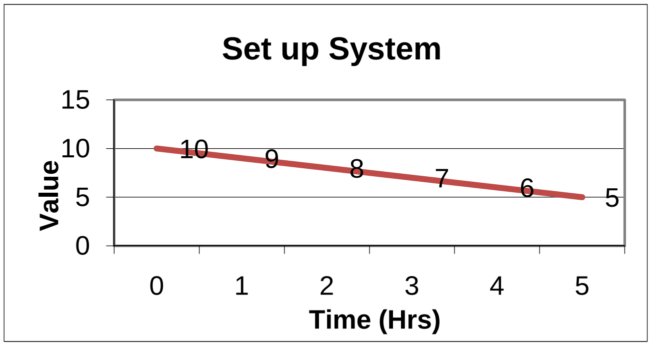

Figure 7. Value Function 5.2

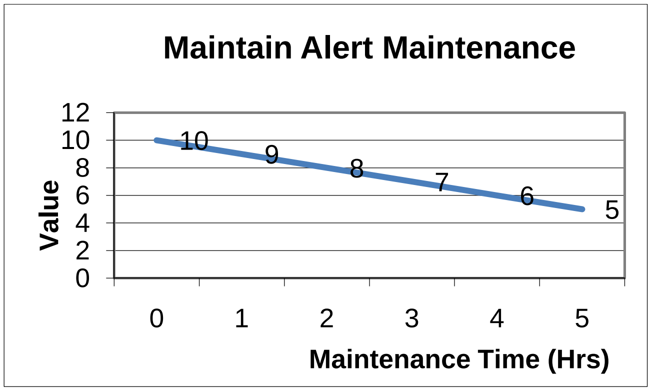

Figure 8. Value Function 6.1

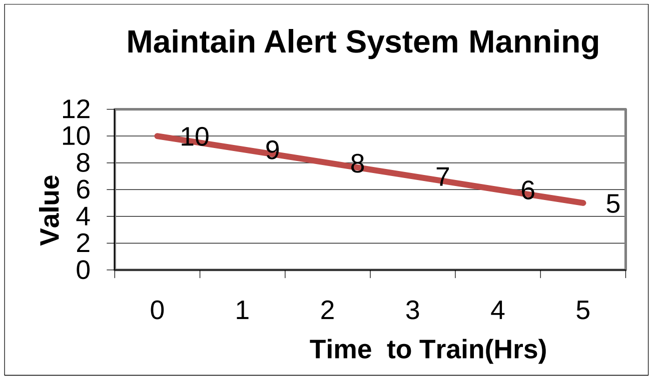

Figure 9. Value Function 6.2

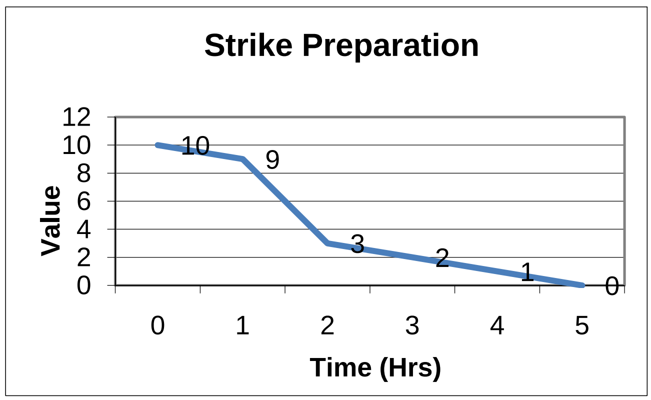

Figure 10. Value Function 7.0

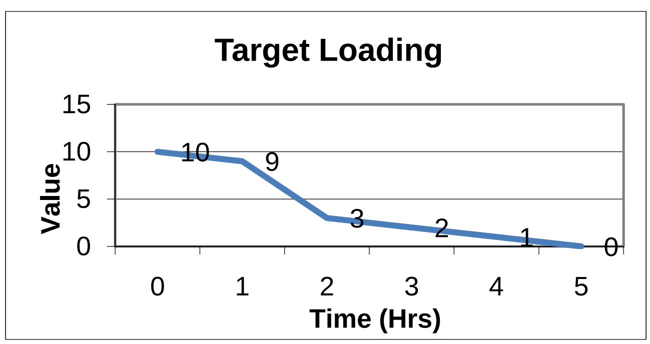

Figure 11. Value Function 8.1

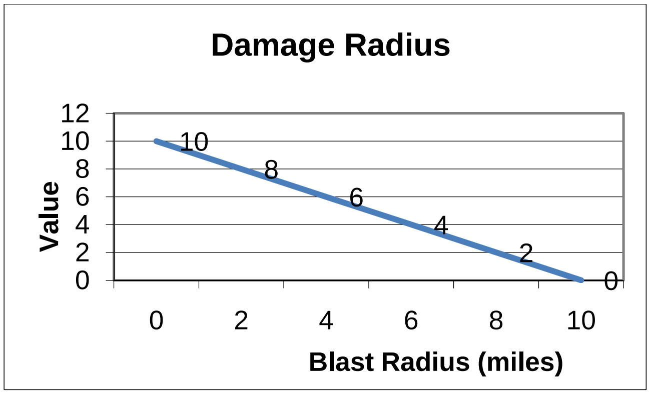

Figure 12. Value Function 8.2.1

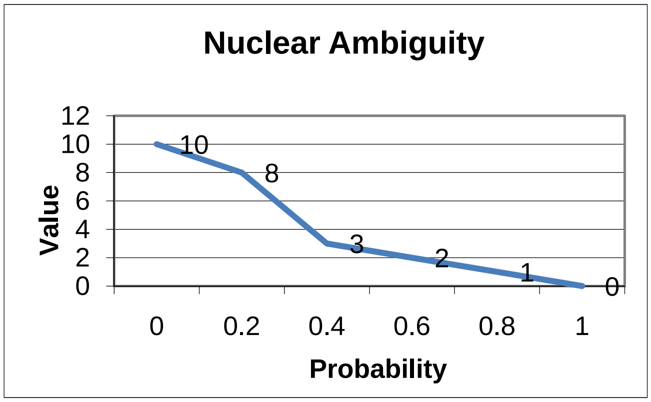

Figure 13. Value Function 8.2.2

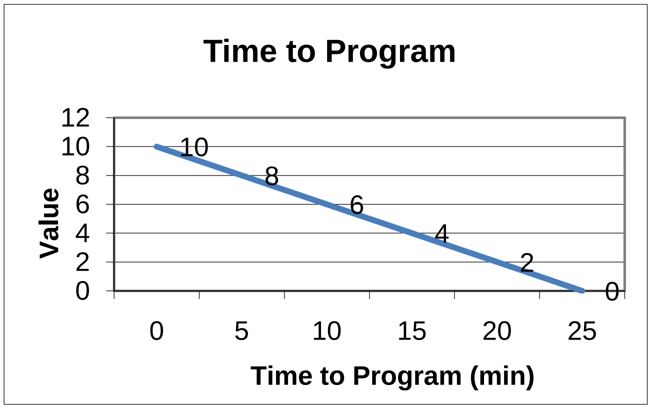

Figure 14. Value Function 8.3

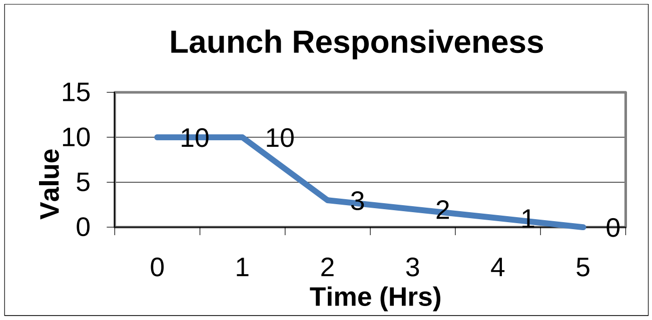

Figure 15. Value Function 10.1

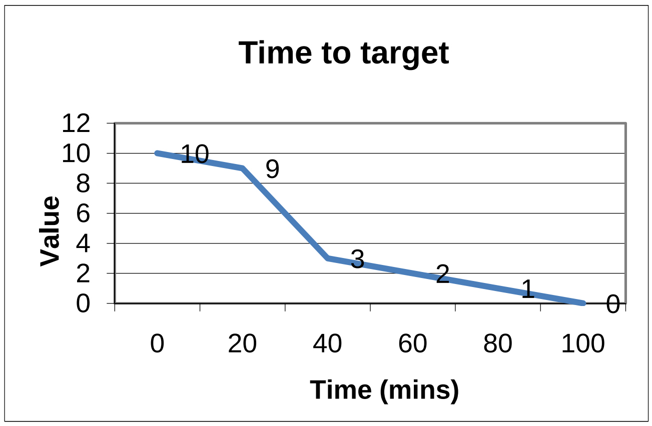

Figure 16. Value Function 10.2

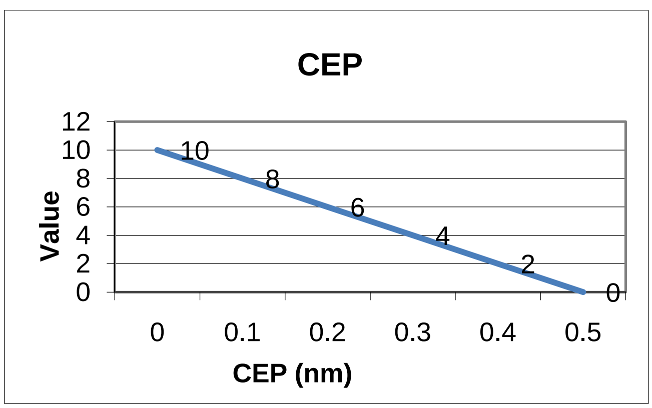

Figure 17. Value Function 10.3.1

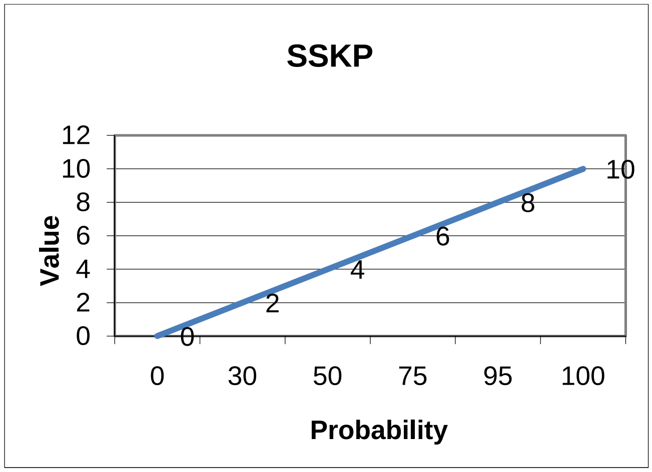

Figure 18. Value Function 10.3.2

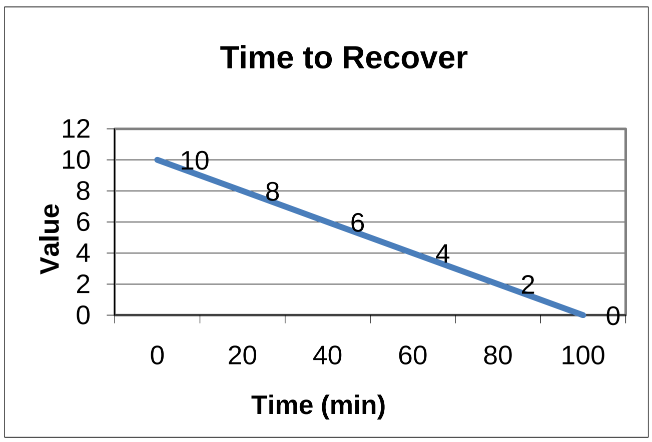

Figure 19. Value Function 10.4

6.1.2. Swing Weighting

The stakeholder identifies the order of importance of the value measures and assists in the weighting of the value measures. Table 8 below summarizes the priority and weights assigned to each value measure.

Table 8. Prioritized Value Measures

	Level of Importance of the Value Measures					
	High		Medium		Low	
High	10.1	100	8.1 / 10.3.1	70	5.1 / 5.2	40
Medium	8.3 / 10.2	90	8.2.1 / 10.3.2	60	10.4	30
Low	8.2.2	80	7.1	50	6.1 / 6.2	20

The measure weights are determined as a ratio of the swing weight to the total swing weight and are summarized in Table 9 below.

Table 9. Swing Weight Solution

Value Measures	Swing Weight	Measure Weight
5.1	40	0.0488
5.2	40	0.0488
6.1	20	0.0244
6.2	20	0.0244
7	50	0.0610
8.1	70	0.0854
8.2.1	60	0.0732
8.2.2	80	0.0976
8.3	90	0.1098
10.1	100	0.1220
10.2	90	0.1098
10.3.1	70	0.0854
10.3.2	60	0.0732
10.4	30	0.0366
Total =	**820**	**1.0000**

6.1.3. Additive Value Model

Applying the swing weights to the value matrix results in the additive value matrix which leads us to a total value score for each alternative. The total value score allows us to prioritize the alternatives with respect to the organizations values. The additive value model is shown in Equation 1 below.

Equation 1

$\mathbf{V}_x = \Sigma[v_i(x) \bullet w_i]$

Where:

$\mathbf{V}_x$ = Total Value Score for alternative x

v_i = value measure i

w_i = swing weight for value measure i

x = alternative

The result of applying the additive value model is a total value score for each alternative and is summarized in Table 10 below.

Table 10. CPGS Alternative Scoring

Candidate Solution	TOTAL VALUE SCORE V(x)
Land Based	7.73
Air Based	5.52
Sea Based	4.79
Ideal	10.00

The results show that the priority for CPGS systems based on the stakeholders values is land based, air based followed by sea based alternatives where the ideal value score is 10. The graph in Figure 20 below captures each alternative in relation to the notional ideal alternative with respect to value focused thinking.

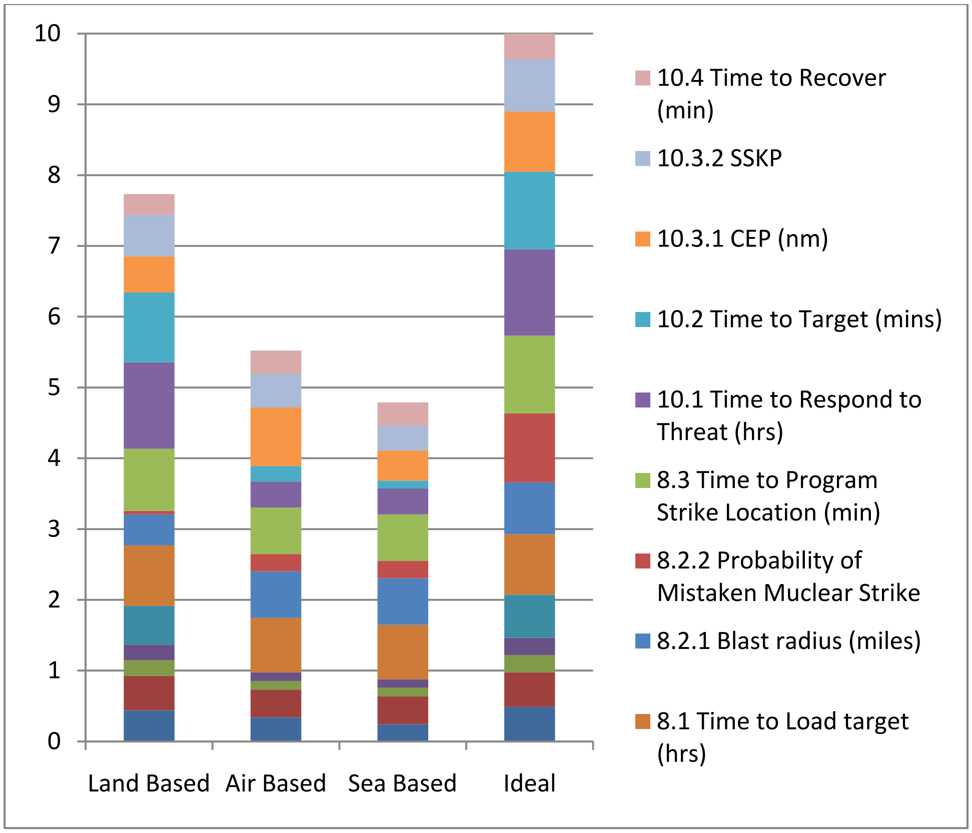

Figure 20. Value Focused Thinking

6.2 Cost vs. Value

Prompt global strike system costs are difficult to capture. Where is the line drawn with regards to system development and platform requirements? The cost estimates shown in Figure 21 below are based on "U.S. Conventional Prompt Global Strike: Issues for 2008 and beyond".

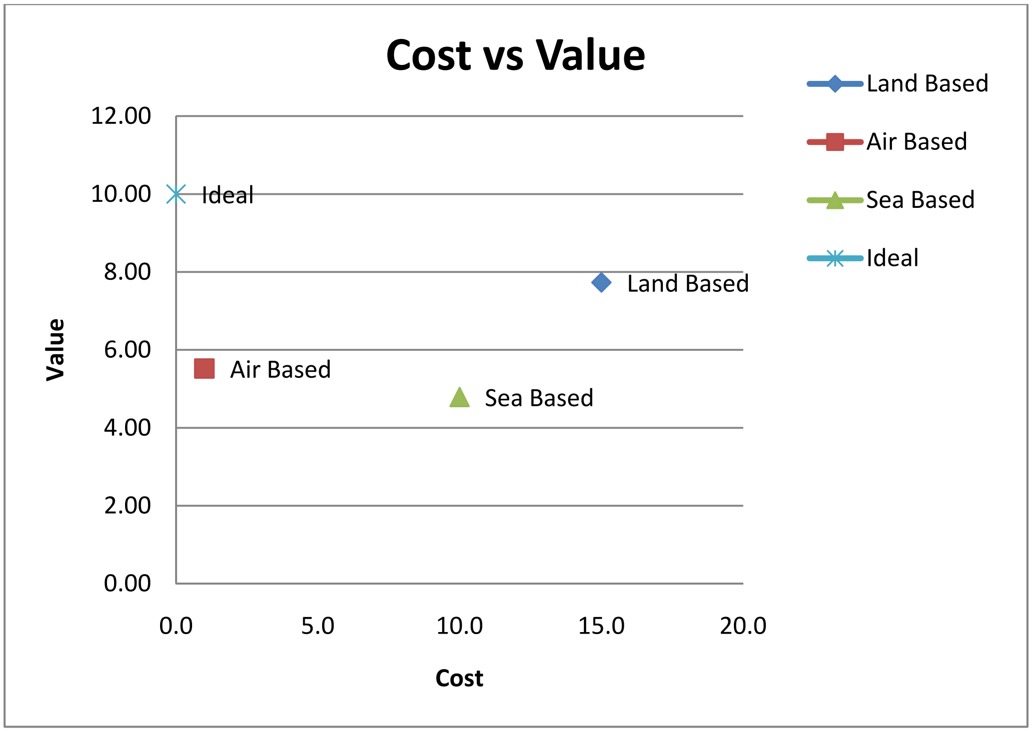

Figure 21. Cost Versus Value

Based on this cost benefit analysis the air based alternative, while slightly less in value than the land based alternative, has significantly less cost than the land based alternative. It would appear that based on the cost and the value that each alternative provides, the air based alternatives are a better "value".

Chapter 7: Threat Assessment

This chapter addresses assessment of the threat in order to determine the impact of cost and probability of an attack on the decision to buy CPGS capability or to not buy CPGS capability. We can use intelligence assessments of the threat but we will never be certain of the actual probabilities associated with the estimate of whether or not we would be attacked by a threat. The cost should we be attacked cannot also be estimated even after the fact due to second and third order effects. This is the case with the attacks on the World Trade Center on

September 11, 2001. The costs were initially estimated at $1.5 billion, a low estimate in every assessment of the situation especially given that deaths are still occurring and being contributed to the health effects suffered during and after the attacks. The loss of life is priceless and you cannot quantify the costs associated with it.

A decision tree is a tool that models decisions and the possible consequences that may occur given the chance of an event occurring and the utility or costs associated with the events. Decision trees are used in decision analysis to help identify the strategy that will allow one to obtain a specified goal. A decision tree is used here in order to show what would cause a decision maker to choose to buy a CPGS capability or to not buy this capability.

Figure 22. CPGS Decision Tree

Given the decision to by a CPGS capability, there is a chance that the capability is effective and a chance that it is not effective. Given that the decision is to buy the CPGS capability, the probability of it being effective, there is a chance of getting attacked or not getting attacked. While the weapon system effectiveness probabilities can be determined, we will never be certain of the probabilities of getting attacked or not. These can be based however on

intelligence estimates. This decision tree was built to be interactive so that "what if" scenarios can be examined. We can vary the probabilities with respect to the effectiveness of the system and the probabilities of getting attacked. We can also vary the value associated with each alternative. As can be seen in figure 22 above, given the values in billions of dollars and the probabilities shown, we would chose to buy the CPGS capability given that the CPGS system is effective 70% of the time, and the actual probability of getting attacked is only 7%. Given the nature of this type of rare event and the potential damage it may cause, it is shown that the CGPS investment is well worth it.

After demonstrating the methodology for CPGS analysis, USSTRATCOM asked that this methodology be applied to the NPGS problem. Next, this paper will examine the nuclear PGS (NPGS) alternatives.

Chapter 8: Nuclear Prompt Global Strike Assessment

The stakeholder requested that the CPGS methodology presented also be applied to the nuclear PGS (NPGS) problem. In so doing, the value measures were relooked and thought of in terms of the nuclear capability. Immediately value measure 8.2.2, nuclear ambiguity, is eliminated as all alternatives clearly have the nuclear capability. The alternatives considered are shown in Table 11 below.

Table 11. NPGS Alternatives

	Current
Land	Minuteman III
	Peacekeeper
Air	B1B
	B-2A
	B52H
Sea	T-LAM
	BMS Trident

Again, the alternatives were screened for feasibility. The results of the feasibility screening are shown in Table 12 below.

Table 12. NPGS Feasibility Screening

Criteria/ Alternatives		Response Time ≤ 1 Hour	All Weather Capable	Available by 2018	Legal, Treaty Pacts Compliance	Strategic Deterrent	Overall Assessment
Land	MM III	Go	Go	Go	Go	Go	Go
	PK	Go	Go	Go	Go	Go	Go
Air	B1B	Go	Go	Go	Go	Go	Go
	B-2A	Go	Go	Go	Go	Go	Go
	B52H	Go	Go	Go	Go	Go	Go
Sea	T-LAM	Go	Go	Go	Go	Go	Go
	BMS Trident	Go	Go	Go	Go	Go	Go

The SDP process is applied again by entering the data in the raw data matrix for each alternative, prioritizing and weighting the value measures, and applying the additive value model to compute the total value scores. The results after applying this process to the NPGS problem is summarizes in Table 13 below.

Table 13. NPGS Alternative Scoring

Candidate Solution	**TOTAL VALUE SCORE V(x)**
Minotaur II Minuteman III	5.68
Minotaur III Peacekeeper	5.63
B1B	6.74
B-2A	6.74
B-52H	6.74
Ship Based Tomahawk LAM	5.17
BMS - Sub-Based Trident	5.10
Ideal	10.00

The results show that the priority for nuclear prompt global strike systems based on the stakeholder's values is the three air based alternatives of the B1B, B-2A and B52H; the land based alternatives of the Minuteman III and the Peacekeeper; and the sea based alternatives of the Tomahawk LAM and the Trident system alternatives. By eliminating the value measure for nuclear ambiguity our priority for the alternatives changes. The air based system alternatives scored higher than the land based alternatives of the Minuteman III and Peacekeeper missiles and the sea based alternatives of the Tomahawk LAM and the Trident missile systems. This can be attributed to the higher responsiveness of the air based alternatives, the higher level of damage radius associated with a land based alternative and the lower accuracy of the sea based alternatives.

Chapter 9: Summary

In summary, the CPGS and the NPGS problems prioritize the use of the system alternatives differently. The CPGS problem advocates the use of land based alternatives over air and sea based alternatives. The NPGS problem advocates the use of air based alternatives over the land and sea based alternatives. This needs to be validated however with the use of classified raw data. Issues with prompt global strike analysis are as follows. In looking at the CPGS problem, the alternatives must be specific and specify the launch platform, the war head, and the weapon to fully define the system. With the possibility of interchanging war heads and launch platforms, the system specifications will vary. Additionally, the types of potential targets vary and drive the selection of the alternatives.

In looking back at the 2006 QDR four key tasks, this analysis helps to present a strategy for meeting the challenges of the future and is a tool that can then be applied to the process of estimating the level of resources necessary to implement this strategy.

There are some key points to consider in the final decision making process. First, our NPGS strategy has always supported the mission with the triad. In answering why would a triad be necessary, one needs to go back to the potential target set. There isn't an approved alternative that can defeat every target type. The QDR emphasized a defense in depth for the future and therefore a triad of CPGS alternatives should be considered in order to have the coverage across target types and a defense in depth.

Second, consider the conventional missile count versus nuclear missile count. The NPGS mission was developed with thousands of missiles on hand to defeat the threat. None were ever fired. Consider gradually building the CPGS mission with tens or hundreds of missiles.

Finally, prioritize funding for the triad based on the value modeling results developed using the SDP in this analysis. By identifying the types of targets expected for each theater, examining the need for land, air or sea based alternatives; it is manageable to then determine the funding necessary for carrying out this strategy.

Chapter 10: Future Work

Future work for this project must start with refining the value measures and swing weights assigned to the value measures to capture the true values of the stakeholder. Once these are solidified, the raw data can be collected and validated. It is recommended that classified data be used in the raw data collection process to see how the classified data would affect the results. Additionally, stakeholder input is needed in the collection of the raw data. Given the revised value measures, swing weights and raw data, the results will be meaningful to the stakeholder and provide a strategy for conventional or nuclear PGS.

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Appendix A: Acronyms

A	
AEF	Air Expeditionary Forces
AFIT	Air Force Institute of Technology
AoA	Analysis of Alternatives
B	
B1B	Lancer Strategic Bomber
B-2A	Stealth Bomber (Spirit)
B52H	Stratofortress Strategic Bomber
BASIC	British American Security Information Council
BDA	Battle Damage Assessment
BMS	Ballistic Missile Submarine
C	
C3	Command, Control and Communication
CAV	Common Aero Vehicle
CBG	Carrier Battle Group
CEP	Circular Error Probable
CM	Cruise Missile
CRS	Congressional Research Service
CSM	Conventional Strike Missile
CTM	Conventional Trident Modification
D	
DoD	Department of Defense
DSB	Defense Science Board
DTRA	Defense Threat Reduction Agency
F	
FALCON	Force Application Launch form Continental US
G	
GSM	Global Strike Missile
H	
HCC	Hague Code of Conduct
HDBT	Hard and deeply buried targets
hrs	hours
I	
ICBM	Intercontinental Ballistic Missile
J	
JFCC-GSI	Joint Functional Component Command for Global Strike and Integration
K	
km	kilometers
L	
LAM	Land Attack Missile
M	
m	meters

min	minutes
MM III	Minuteman III
MTCR	Missile Technology Control Regime
N	
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NCA	National Command Authority
NDI	National Defense Industrial Association
NGLT	Next Generation Launch Technology
nm	Nautical miles
NPGS	Nuclear Prompt Global Strike
NSB	Naval Studies Board
O	
ORCEN	Operations Research Center of Excellence
OSD	Office of the Secretary of Defense
P	
PK	Peacekeeper
Q	
QDR	Quadrennial Defense Review
S	
SLBM	Submarine-Launched Ballistic Missile
SDP	Systems Decision Process
SORT	Strategic Offensive Reductions Treaty
SSKP	Single Shot Kill Probability
START	Strategic Arms Reduction Treaty
T	
TBM	Tactical Ballistic Missile
T-LAM	Tomahawk Land Attack Missile
U	
USSTRATCOM	United States Strategic Command
USMA	United States Military Academy
V	
v_i	Value measure i
V(x)	Total value score
W	
w_i	Swing weight for value measure i
WMD	Weapons of Mass Destruction
X	
x	Alternative

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14. ABSTRACT
The Quadrennial Defense Review in 2006 made several decisions which affect Strategic Command's (STRATCOM) mission areas, specifically in the area of conventional prompt global strike capability. There is a need for analysis of issues associated with Strategic Command (STRATCOM) lines of operation in the areas of Strategic Deterrence/Nuclear Operations. Global Strike with respect to the conventional strike capability is explored to include prompt global strike as follow-on to the joint force enabler to respond to various threats. The Systems Decision Process (SDP) is applied to analyze CPGS alternatives based on a value focused thinking methodology in order to develop a strategy for meeting the challenges of today and to help prioritize the implementation of this strategy

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